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# ARMORED MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

~~CONFIDENTIAL~~

INDEXED

Third Partial Report

On

PROJECT NO. T-5 - TEST OF FLAMEPROOFED CLOTHING

Subject: Effects of Wearing Flameproofed Clothing in Hot Environments

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Project No. T-5

~~CONFIDENTIAL~~

31 July 1945





ARMORED MEDICAL RESEARCH LABORATORY  
Fort Knox, Kentucky

Project No. T-5  
SPMEA 727-2

31 July 1945

1. PROJECT: No. T-5 - Test of Flameproofed Clothing. Third Partial Report.  
Subject: Effects of Wearing Flameproofed Clothing in Hot Environments.

a. Authority: Letter, 6th Indorsement, SPMDO 421, ASF, SGO, Washington 25, D. C., 7 December 1944.

b. Purpose: To evaluate the effects of wearing two new types of flameproofed clothing in hot environments.

2. DISCUSSION:

The first two partial reports on this subject were studies on the effect of wearing clothing which had been flameproofed and gasproofed by CC-2, M1, impregnating mixtures. The clothing type "X" was considered unsatisfactory because the flameproofing properties disappeared quickly on use. Type "D" flameproofed clothing was considered to be satisfactory.

After these garments had been tested, the Chemical Warfare Service reported two new types of flameproofed clothing. One was treated by a foam impregnation process. Essentially the same impregnating materials were used in this as for types X and D. The other was treated by an antimony trioxide-vinylite impregnation. This latter method affords flameproof protection alone. In view of the fact that the threat of gas warfare is only potential but flame presents a constant danger to tank crewmen, the immediate need of the Armored Force is flameproofed clothing which is as acceptable as the standard issue garments.

The following study was carried out to determine (1) the heat load imposed by these two types of flameproofed garments and (2) the general acceptability of the clothing. The garments were worn by acclimatized subjects working in a hot environment simulating that which may be found in buttoned-up tanks (D.B. 120°F. - 88°F.).

3. CONCLUSIONS:

a. Clothing treated to provide protection against flame alone (antimony trioxide) had a heat load no greater than that of untreated herringbone twill.

b. Garments which were rendered gasproofed and flameproofed by the foam impregnation process also imposed a heat load like untreated herringbone twill.

c. Unlaundered, foam-process impregnated garments should not be worn since they produced marked chemical irritation of the skin.





C O N F I D E N T I A L

4. RECOMMENDATIONS:

a. That both antimony trioxide or laundered foam-process impregnated herringbone twill garments be evaluated from the standpoint of retention of adequate flameproofness following continued wear and laundering.

b. That either type of garment be considered suitable for issue to troops if flameproof qualities are found to be satisfactory.

Submitted by:

Ludwig W. Eichna, Major, MC  
Steven M. Horvath, Major, SnC  
Walter B. Shelley, Captain, MC

Assisted by:

Howard Golden, Tec 3  
Arthur F. Kunes, Tec 3  
John E. Wagar, Tec 3  
Kenneth C. Davis, Tec 3  
James P. Stack, Tec 3  
Robert A. Kleinmann, Tec 4  
William J. Robinson, Jr., Tec 5  
James W. Gregg, P-4

APPROVED

*Willard Machle*  
WILLARD MACHLE  
Colonel, Medical Corps  
Commanding

3 Incls.

- #1 - Appendix
- #2 - Table
- #3 - Charts 1 thru 3

C O N F I D E N T I A L





APPENDIX

1. Procedure:

a. Experimental Conditions

All observations were made in the laboratory hot room during April and May, 1945. Ten (10) normal, healthy, physically fit soldiers were selected for this test. Their ages ranged from 19 to 23 years, average 21; their weights, from 134 to 184 pounds, average 153; their heights, from 66 to 71 inches, average 68. The entire test was carried out in an environment of D.B. 120°F., W.B. 88°F., R.H. 28%. This environment was selected as representative of the extreme situation to which a tank crew might be subjected when operating a buttoned-up vehicle in hot climates. The procedures described in Partial Report No. 1\* were followed.

b. Clothing

The following types and assemblies were worn during this study:

- (1) Herringbone Twill, Single Layer - half wool socks, service shoes, cotton shorts, new two piece fatigue uniform of herringbone twill.
- (2) Foam Process, Flameproofed Assembly, Unlaundered Single Layer - half wool socks, service shoes, cotton shorts, unlaundered two piece uniform of flameproofed herringbone twill.
- (3) Foam Process, Flameproofed Assembly, Laundered Single Layer - half wool socks, service shoes, cotton shorts, laundered two piece uniform of flameproofed herringbone twill.
- (4) Antimony Trioxide Flameproofed Assembly, Single Layer - half wool socks, service shoes, cotton shorts, unlaundered two piece uniform of flameproofed herringbone twill.

All the flameproofed garments were prepared by Chemical Warfare Service. The foam process impregnated clothing had been subjected to an aqueous emulsion treatment. The impregnating formula was:

XXCC No. 2/ZnO/CP\*\*/PVA<sup>1</sup>/ME<sup>11</sup>/H<sub>2</sub>O/28/28/28/1.4/1.4/91.6

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\* AMRL Project No. T-5, Test of Flameproofed Clothing, First Partial Report - Subject: Physiologic Effects of Wearing Flameproofed Clothing in Hot Environments, 17 July 1945.

\*\* Chlorinated Paraffin

<sup>1</sup> Polyvinyl Alcohol

<sup>11</sup> Duponal ME (Sodium lauryl sulfate)







This impregnation rendered the garment both flameproof and gasproof. The amount of pick-up was 31 to 33%. Two sets of these garments were used, one which was unlaundered and the other which had been given one (1) CMC Formula G laundering. The antimony trioxide flameproofed garments were made from fabric which had received treatment with antimony trioxide, vinylite and pigments in a solvent of methyl ethyl ketone. The amount of pick-up of flameproofing material was 30 to 35% of the original weight of the cloth.

2. Results:

a. Heat Load

Men who had been acclimatized to marching at a D.B. 120°F., W.B. 88°F. for 13 days were used. During the period of testing each of the ten (10) subjects wore new herringbone twill, foam process unlaundered, foam process laundered and antimony trioxide garments. On each day, some men were wearing all four (4) types of treated garments according to a Latin Square. The physiological indications of the heat load imposed by the flameproofed clothing are presented in Charts 1, 2, and 3. The responses of the subjects clothed in herringbone twill were used in each of the charts as the common reference. All of the men were able to easily finish the required four (4) hours of marching. It was apparent that the heat load of the flameproofed garments was similar to that imposed by new herringbone twill fabric.

Subjectively the men preferred the laundered foam process flameproofed twill. The main objection to the antimony trioxide flameproofed twill was the impression that it was too heavy. None of the men wanted to wear the unlaundered foam process flameproofed twill because it caused considerable skin irritation. A single day's wear resulted in a marked contact dermatitis in all areas where the clothing rubbed the skin. This was so severe that in most cases the men would have refused to wear the garments another day except under direct order.

b. Physical Characteristics of the Clothing

- (1) Unlaundered, foam process flameproofed twill - This clothing was stiff and waxy with a whitish powder on the surfaces. It absorbed sweat quite readily but not to the same extent as HBT.
- (2) Laundered, foam process flameproofed twill - The general properties were similar to the unlaundered foam process garment except that the loose surface deposit of chemicals had been eliminated. The ease of wetting was not appreciably different from the unlaundered clothing.
- (3) Antimony trioxide treated herringbone twill - This garment had the appearance of untreated herringbone twill except that it had a smoother finish. It was not stiff or waxy. It wet as readily as new HBT. Because of its increased ability to absorb water, these garments in use were heavier than either HBT or foam process flameproofed twill.







TABLE 1

The Physiologic Responses of Working Men Clad in Different  
Flameproofed Garments and in Herringbone Twill

D.B. 120°F. - W.B. 88°F.

| CLOTHING                                       | RECTAL TEMPERATURE OF |      |       |       |       | PULSE RATE/MIN. |     |     |     |     | SKIN TEMPERATURE<br>(Avg. Wtg.)<br>OF |       | WEIGHT LOSS<br>(Sweat)<br>Gmo./Hr. |       |       |
|--|-----------------------|------|-------|-------|-------|-----------------|-----|-----|-----|-----|---------------------------------------|-------|------------------------------------|-------|-------|
|  | Person                | 0    | 1     | 2     | 3     | 4               | 0   | 1   | 2   | 3   | 4                                     | Init. |                                    | 1 Hr. | 4 Hrs |
| HERRINGBONE TWILL                              | Abe                   | 97.9 | 100.7 | 101.5 | 101.7 | 101.7           | 105 | 126 | 117 | 126 | 129                                   | 97.2  | 99.2                               | 100.3 | 1128  |
|  | Atw                   | 98.5 | 100.8 | 101.6 | 101.5 | 101.4           | 114 | 145 | 132 | 120 | 126                                   | 95.8  | 99.0                               | 98.8  | 1548  |
|  | Bud                   | 97.6 | 100.9 | 101.2 | 101.4 | 101.3           | 126 | 150 | 120 | 120 | 123                                   | 93.5  | 98.5                               | 98.1  | 1412  |
|  | Del                   | 98.4 | 100.7 | 101.6 | 102.4 | 103.0           | 102 | 129 | 126 | 141 | 132                                   | 97.3  | 99.4                               | 100.9 | 1404  |
|  | Ger                   | 98.2 | 101.1 | 102.5 | 103.2 | 104.3           | 108 | 129 | 132 | 105 | 120                                   | 99.5  | 98.6                               | 101.6 | 925   |
|  | Har                   | 97.8 | 100.4 | 101.1 | 100.9 | 100.4           | 114 | 117 | 117 | 105 | 105                                   | 98.8  | 99.0                               | 98.0  | 1246  |
|  | Koz                   | 98.7 | 100.7 | 101.9 | 102.5 | 102.9           | 93  | 126 | 120 | 117 | 132                                   | 99.0  | 97.1                               | 100.5 | 1292  |
|  | Mor                   | 98.3 | 101.0 | 102.3 | 102.7 | 103.8           | 105 | 150 | 126 | 117 | 138                                   | 99.1  | 97.1                               | 101.1 | 1227  |
|  | To1                   | 97.9 | 100.4 | 101.1 | 101.3 | 101.3           | 102 | 117 | 93  | 105 | 108                                   | 98.0  | 98.3                               | 98.6  | 1013  |
|  | Min                   | 98.2 | 100.6 | 101.7 | 101.9 | 101.5           | 109 | 123 | 123 | 123 | 120                                   | 98.1  | 99.0                               | 99.2  | 1230  |
|  | AVG.                  | 98.2 | 100.7 | 101.6 | 101.9 | 102.2           | 107 | 131 | 121 | 118 | 123                                   | 98.2  | 98.9                               | 99.7  | 1312  |
| FLAMEPROOFED TWILL<br>Foam Process (Laundered) | Abe                   | 97.8 | 100.1 | 100.4 | 99.9  | 100.1           | 105 | 126 | 108 | 108 | 120                                   | 97.7  | 99.1                               | 98.2  | 1600  |
|  | Atw                   | 98.5 | 101.5 | 102.0 | 101.6 | 101.6           | 132 | 140 | 120 | 129 | 132                                   | 98.9  | 98.7                               | 99.4  | 1280  |
|  | Bud                   | 98.2 | 101.0 | 102.3 | 102.2 | 102.1           | 114 | 123 | 135 | 123 | 117                                   | 99.0  | 98.2                               | 98.9  | 1518  |
|  | Del                   | 98.8 | 100.9 | 101.1 | 101.0 | 100.8           | 105 | 123 | 108 | 117 | 114                                   | 98.9  | 98.9                               | 99.0  | 1969  |
|  | Ger                   | 98.9 | 101.5 | 102.6 | 102.8 | 103.7           | 117 | 144 | 126 | 120 | 129                                   | 97.9  | 99.1                               | 101.3 | 994   |
|  | Har                   | 97.8 | 101.2 | 101.7 | 101.7 | 101.8           | 102 | 129 | 126 | 108 | 132                                   | 97.7  | 99.6                               | 99.3  | 1682  |
|  | Koz                   | 98.5 | 100.8 | 101.9 | 101.6 | 101.7           | 120 | 123 | 150 | 114 | 117                                   | 98.2  | 98.7                               | 99.4  | 1370  |
|  | Mor                   | 98.0 | 101.0 | 102.4 | 102.7 | 103.1           | 104 | 132 | 135 | 108 | 129                                   | 97.4  | 99.1                               | 101.4 | 1290  |
|  | To1                   | 98.4 | 101.3 | 102.0 | 102.5 | 102.7           | 90  | 129 | 117 | 120 | 117                                   | 97.4  | 98.6                               | 99.2  | 1509  |
|  | Min                   | 98.5 | 101.6 | 103.4 | 103.3 | 103.1           | 108 | 135 | 123 | 144 | 146                                   | 97.4  | 99.9                               | 100.5 | 1192  |
|  | AVG.                  | 98.3 | 101.1 | 102.0 | 101.9 | 102.1           | 111 | 131 | 122 | 119 | 125                                   | 98.0  | 99.1                               | 99.6  | 1600  |





TABLE 1 (Cont'd.)

| CLOTHING   |  | RECTAL TEMPERATURE OF |       |       |       |       | PULSE RATE/MIN. |     |     |     |       | SKIN TEMPERATURE<br>(Wk. Avg.)<br>°F |        | WEIGHT LOSS<br>(Sweat)<br>Gm./Hr. |      |      |
|--|--|-----------------------|-------|-------|-------|-------|-----------------|-----|-----|-----|-------|--------------------------------------|--------|-----------------------------------|------|------|
| NAME   | 0  | 1                     | 2     | 3     | 4     | 0     | 1               | 2   | 3   | 4   | Init. | 1 Hr.                                | 4 Hrs. |                                   |      |      |
| FLAMEPROOFED TWILL<br>Form Process (Unlaundered) | Abe  | 97.8                  | 100.5 | 101.2 | 101.1 | 101.3 | 96              | 138 | 117 | 126 | 132   | 98.0                                 | 98.5   | 99.0                              | 1126 |      |
|  | Ala  | 98.8                  | 101.2 | 101.6 | 101.5 | 102.3 | 108             | 129 | 129 | 126 | 138   | 97.9                                 | 98.4   | 100.2                             | 1352 |      |
|  | Bud  | 97.9                  | 100.6 | 101.2 | 101.3 | 101.0 | 117             | 126 | 129 | 120 | 126   | 98.2                                 | 98.3   | 98.8                              | 1386 |      |
|  | Del  | 98.3                  | 101.4 | 102.3 | 102.4 | 102.4 | 132             | 150 | 120 | 126 | 132   | 93.4                                 | 98.4   | 100.1                             | 1270 |      |
|  | Ger  | 98.7                  | 101.4 | 102.6 | 103.8 | 104.3 | 99              | 132 | 132 | 129 | 126   | 98.1                                 | 99.5   | 102.3                             | 787  |      |
|  | Hat  | 98.0                  | 100.7 | 101.5 | 101.4 | 101.5 | 114             | 126 | 117 | 111 | 114   | 98.2                                 | 98.7   | 100.2                             | 1440 |      |
|  | Koz  | 98.2                  | 101.0 | 102.1 | 102.2 | 103.2 | 90              | 132 | 111 | 126 | 141   | 98.5                                 | 99.4   | 101.1                             | 1065 |      |
|  | Met  | 98.5                  | 100.7 | 101.7 | 102.3 | 103.3 | 108             | 126 | 123 | 120 | 132   | 98.0                                 | 99.0   | 100.9                             | 1150 |      |
|  | Tol  | 97.8                  | 100.9 | 101.8 | 101.9 | 102.0 | 111             | 123 | 120 | 105 | 102   | 96.9                                 | 98.3   | 99.3                              | 1547 |      |
|  | Zin  | 93.0                  | 100.9 | 102.1 | 102.1 | 102.2 | 111             | 120 | 108 | 117 | 126   | 97.8                                 | 98.6   | 100.4                             | 1599 |      |
|  | AVG.   | 98.2                  | 100.9 | 101.8 | 102.0 | 102.4 | 109             | 130 | 121 | 121 | 128   | 98.0                                 | 98.7   | 100.2                             | 1247 |      |
|  | FLAMEPROOFED TWILL<br>Antimony Oxide Treated | Abe                   | 97.6  | 100.1 | 100.8 | 100.7 | 100.7           | 105 | 132 | 120 | 117   | 120                                  | 98.3   | 98.0                              | 98.9 | 1402 |
|  |  | Ala                   | 98.5  | 100.5 | 101.1 | 100.7 | 100.7           | 114 | 126 | 126 | 120   | 123                                  | 97.4   | 98.4                              | 98.4 | 1764 |
| Bud  |  | 98.4                  | 101.2 | 102.0 | 102.1 | 102.2 | 96              | 126 | 120 | 132 | 156   | 93.3                                 | 99.5   | 98.4                              | 1505 |      |
| Del  |  | 97.9                  | 100.6 | 101.2 | 101.1 | 101.2 | 102             | 132 | 129 | 114 | 120   | 99.7                                 | 99.0   | 99.4                              | 1665 |      |
| Ger  |  | 98.2                  | 100.5 | 101.5 | 102.1 | 102.3 | 105             | 126 | 123 | 117 | 120   | 97.5                                 | 98.2   | 100.0                             | 1062 |      |
| Hat  |  | 98.1                  | 100.9 | 101.8 | 101.8 | 102.0 | 117             | 159 | 135 | 120 | 132   | 98.3                                 | 98.6   | 99.3                              | 1336 |      |
| Koz  |  | 98.4                  | 100.2 | 101.1 | 101.8 | 102.1 | 108             | 117 | 114 | 120 | 120   | 99.2                                 | 98.4   | 99.7                              | 1266 |      |
| Met  |  | 93.4                  | 101.0 | 102.4 | 103.1 | 104.2 | 111             | 141 | 126 | 144 | 126   | 97.3                                 | 99.2   | 101.3                             | 1290 |      |
| Tol  |  | 98.1                  | 101.1 | 101.9 | 101.7 | 102.4 | 96              | 126 | 108 | 117 | 117   | 98.5                                 | 98.1   | 99.2                              | 1498 |      |
| Zin  |  | 93.5                  | 101.5 | 102.5 | 102.7 | 103.0 | 126             | 138 | 108 | 129 | 129   | 98.6                                 | 99.2   | 99.1                              | 1362 |      |
| AVG.   |  | 98.2                  | 100.8 | 101.6 | 101.4 | 102.1 | 107             | 132 | 121 | 123 | 126   | 98.2                                 | 98.7   | 99.4                              | 1426 |      |

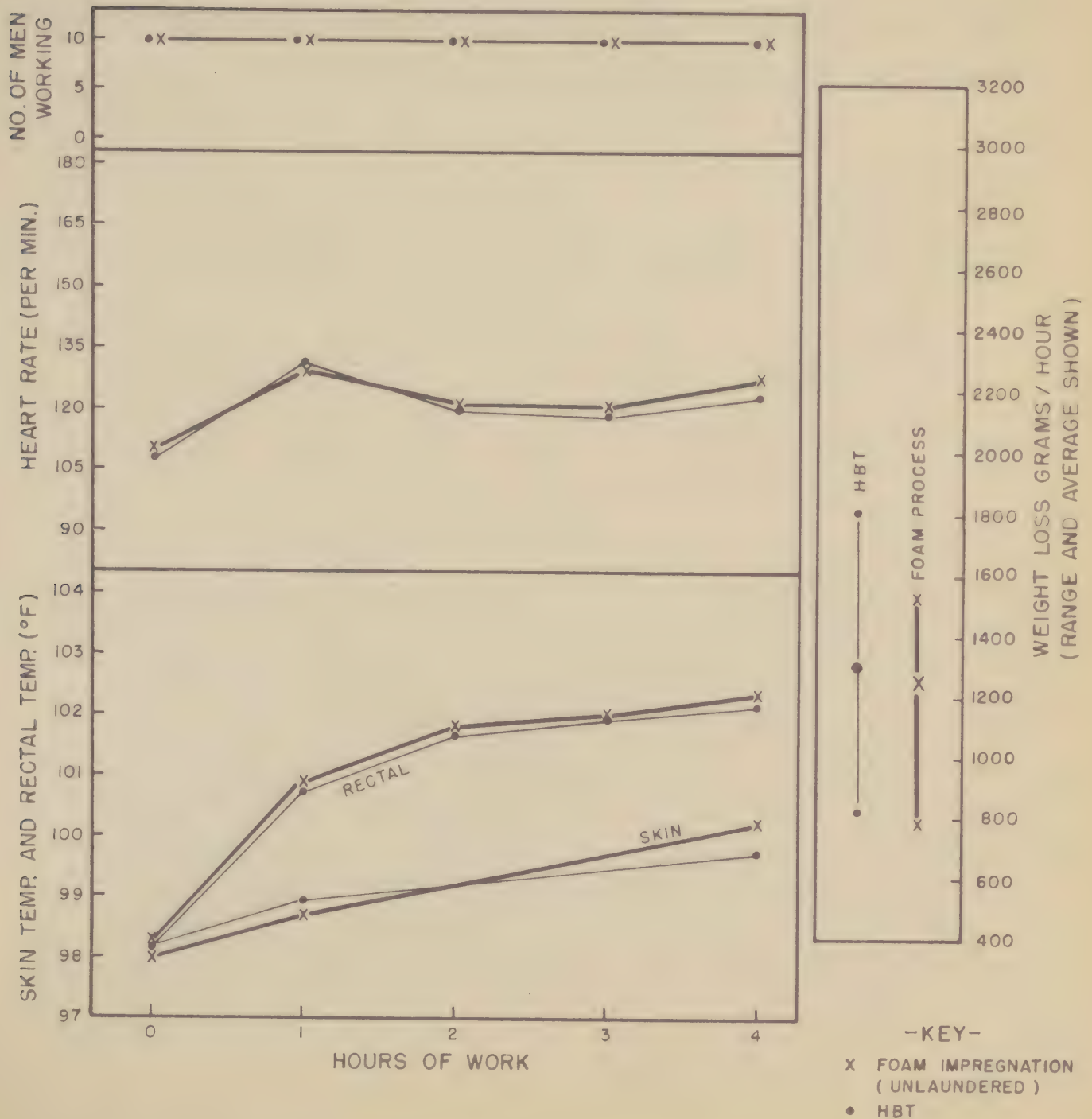




# CHART I

AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING  
UNLAUNDERED FOAM PROCESS FLAMEPROOFED TWILL  
AND HERRINGBONE TWILL

D.B. 120° F - W.B. 88° F



Incl. #3

CHART I

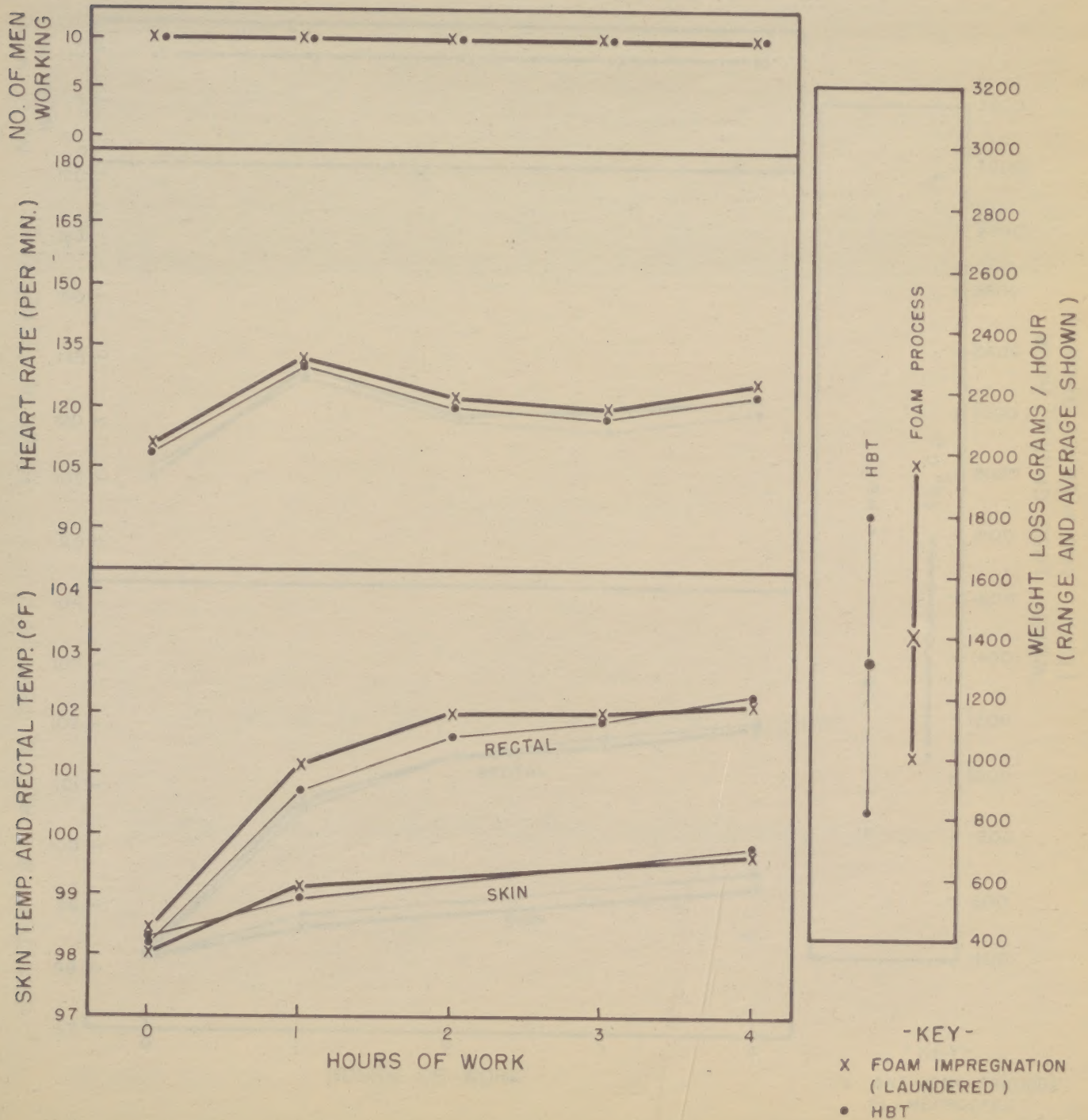




CHART 2

AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING  
LAUNDERED FOAM PROCESS FLAMEPROOFED TWILL  
AND HERRINGBONE TWILL

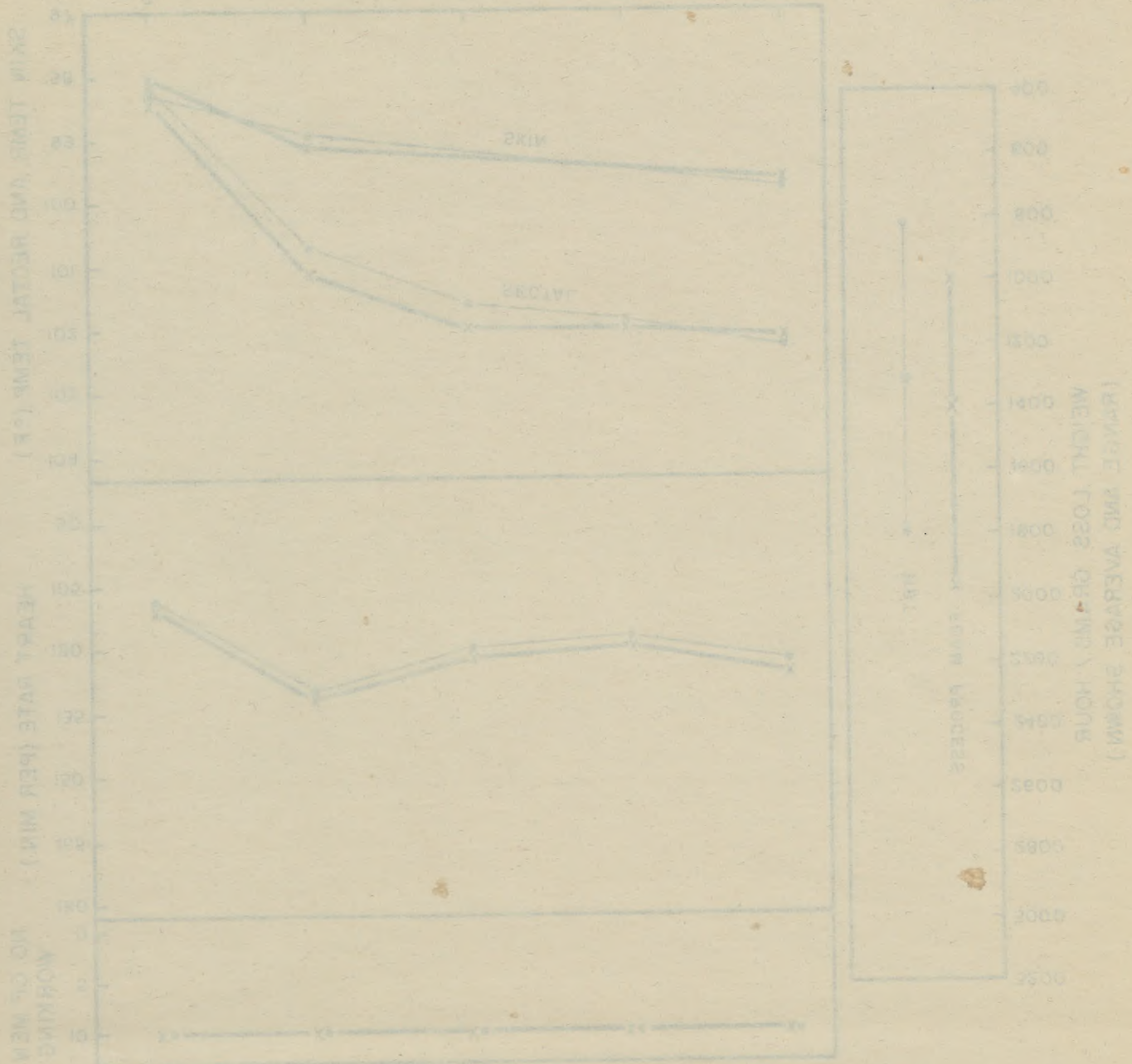
D.B. 120° F - W.B. 88° F



Incl. #3

HOURS OF WORK

• H&I  
 ○ FLAMPROOFED  
 x FOAM IMPREGINATION  
 KEY



D.B. 150°F - W.B. 99°F

AND HEBBINGSTONE TWILL

FLAMPROOFED FOAM PROCESS FLAMPROOFED TWILL

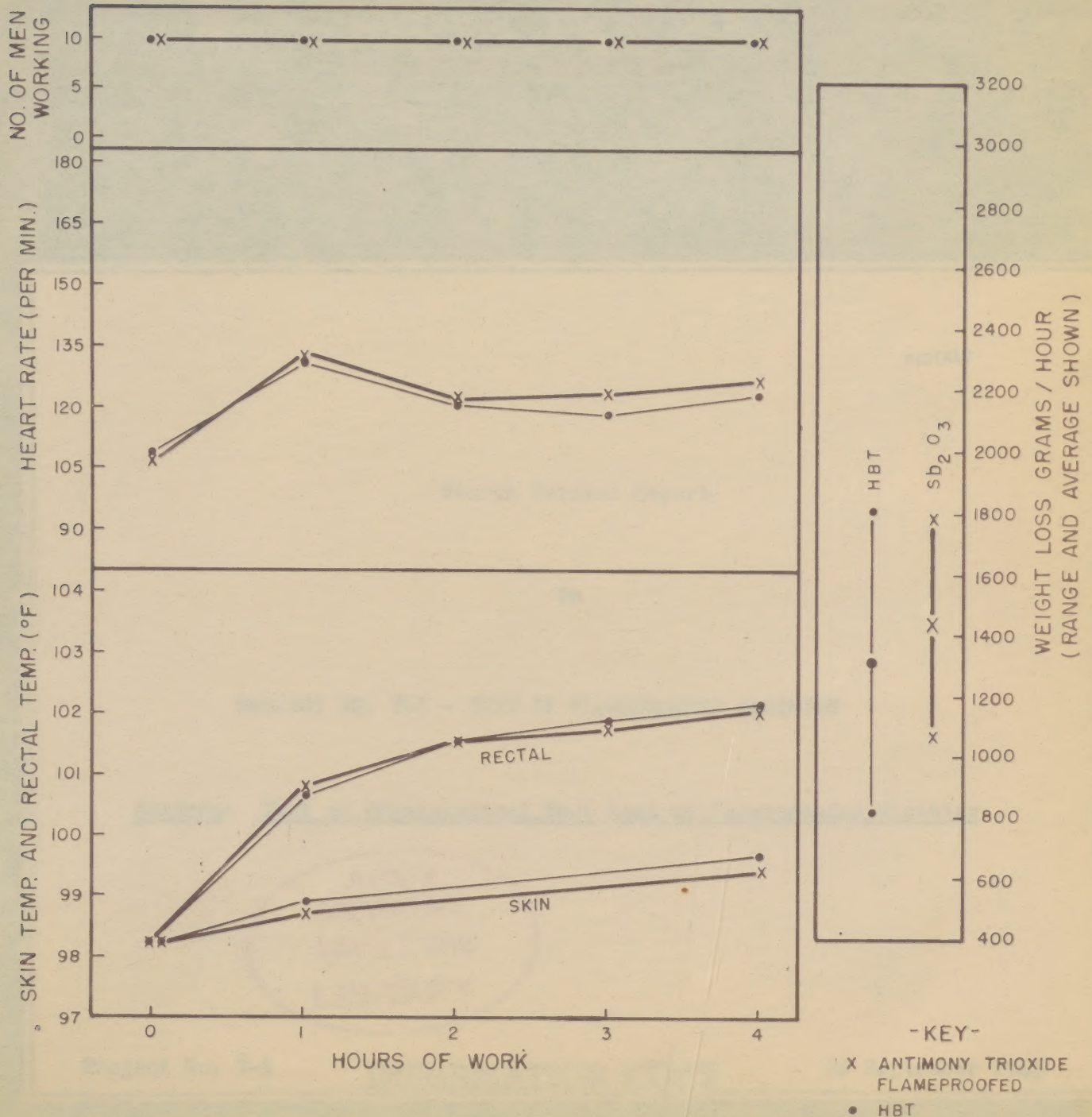
AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING



CHART 3

AVERAGE PHYSIOLOGIC RESPONSES OF WORKING MEN WEARING  
ANTIMONY TRIOXIDE FLAMEPROOFED TWILL  
AND HERRINGBONE TWILL

D.B. 120°F - W.B. 88°F



Incl. #3

CHART 3

